A Study of the Acid-Soluble Phosphoric Acid in Eggs

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DISSERTATION

Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Pure Science, Columbia University.

By

LOUIS PINE, B.S., A.M.

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TO MY WIFE

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L. P.

New York Station,
Bureau of Chemistry,
United States Department of Agriculture,

May, 1923.

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A STUDY OF THE ACID-SOLUBLE PHOSPHORIC ACID IN EGGS

By Louis Pine

(From the New York Laboratory, Bureau of Chemistry, United States Department of Agriculture)

INTRODUCTION

Chapin and Powick (1), while working on a method for the estimation of the inorganic phosphoric acid in tissues and food products, found that the inorganic phosphoric acid in eggs was greatly increased on decomposition. They were interested only in the method and did not make an extensive study of the quantitative changes in inorganic phosphoric acid in eggs, as a test for decomposition.

The total phosphorus pentoxide in eggs is given by Sherman (2) as 0.37 per cent, by Cook (3) as 0.67 per cent and by Chapin and Powick (1) as 0.5 per cent. About 96 per cent (1) of the total phosphorus is organically combined. Practically all of the organic phosphorus is in the yolk. The organic compounds of the yolk containing phosphorus are proteins, chiefly vitellin, 15.7 per cent (4); phospholipoids, chiefly lecithin, 11 per cent (5); and glycerophosphoric acid, 1.2 per cent (6), of the yolk.

Upon decomposition, the vitellin yields inorganic phosphoric acid (7) and the phospholipoids liberate glycerophosphoric and inorganic phosphoric acids (8). Chapin and Powick (1) found from 16 to 18 mgs. of inorganic phosphorus pentoxide per 100 grams of fresh eggs and from 41 to 129 mgs. per 100 grams of decomposed eggs, depending upon the degree of deterioration. Cook (3) found a decrease in lecithin in cold storage eggs.

Since the phospholipoids on decomposition liberate glycerophosphoric acid as well as inorganic phosphoric acid, the increase in the inorganic phosphoric acid alone would not be a complete measure of the decomposition. The increase in the total acid-soluble phosphoric acid, containing both the inorganic and the glycerophosphoric acids, would be a better index of the decomposition of the organic phosphorus compounds of the yolk.

This work was undertaken to ascertain whether the increase of acid-soluble phosphoric acid in whole egg and yolk could be made a test for decomposition. The white of egg was not considered in this investigation because it contains little organically combined phosphorus, and therefore the increase of acid-soluble phosphoric acid on decomposition would be neglible.

METHOD FOR THE ESTIMATION OF THE ACID-SOLUBLE PHOSPHORIC ACID IN LIQUID WHOLE EGG AND YOLK

There are three important steps in the determination of the acid-soluble phosphoric acid in eggs: the extraction, the destruction of organic matter, and the final estimation of phosphoric acid. The extraction is made by a modification of the Chapin and Powick method (1). The organic matter is destroyed by digestion with concentrated sulphuric and nitric acids. The phosphoric acid is determined as magnesium pyrophosphate.

EXTRACTION.—Fifty grams of whole egg or 25 grams of yolk are weighed out in a 500 c.c. Erlenmeyer flask. 200 c.c. of hydrochloric acid solution, containing 1 c.c. of concentrated hydrochloric acid (0.5:100), and 8 grams of picric acid are added. The flask is stoppered with a rubber stopper and shaken vigorously at frequent intervals, at least every ten minutes, for one hour. The contents is then filtered through a folded filter paper, 24 cm. for whole egg and 18.5cm. for yolk. The filtration should not be allowed to proceed for more than three-quarters of an hour.

DESTRUCTION OF ORGANIC MATTER.—125 to 150 c. c. of the filtrate are transferred to a 500 c. c. Kjeldahl flask. Four glass beads, 10 c. c. of concentrated sulphuric acid and 10 c. c. of concentrated nitric acid are added. The mixture is boiled down until white fumes appear. About 2 c. c. of concentrated nitric acid are added drop by drop and the mixture is boiled again until white fumes appear. This last step is repeated four times. The mixture is boiled ten minutes longer and then allowed to cool. About 25 c. c. of water are added and the solution boiled until the brown fumes are driven off.

ESTIMATION OF PHOSPHORIC ACID.—The solution, while still hot, is transferred to a 400 c. c. beaker and the flask washed with small amounts of hot water until the volume of solution in the beaker measures about 100 c. c. The phosphoric acid is then determined by the official gravimetric method (9).

The total volume of solution in the extraction mixture is found by adding to the 200 c. c. of hydrochloric acid solution the volume of water contained in 50 grams of whole egg or 25 grams of yolk and in 8 grams of picric acid (1).

Water in eggs is determined in vacuum at 55° C. (10) and in picric acid in vacuum over sulphuric acid (11).

Note 1.—Rubber stoppers absorb picric acid. They can be cleaned by soaking in water and changing the water several times.

Note 2.—The amount of filtrate collected in three-quarters of an hour depends upon the grade of filter paper used. A rapid filter paper must be used.

A STUDY OF THE CHAPIN AND POWICK METHOD (1) FOR THE EXTRACTION OF THE ACID-SOLUBLE PHOSPHORIC ACID.

Chapin and Powick extract the acid-soluble phosphoric acid for two hours with 200 c. c. of water, 10 c. c. of 2.5 normal hydrochloric acid and 5 to 8 grams of picric acid. Their method was tested by varying the amounts of the reagents and the time of extraction.

Effect of Varying the Amounts of Hydrochloric Acid.—10 c. c. of 2.5 normal hydrochloric acid are equal to about 2 c. c. of the concentrated acid. The amount of concentrated hydrochloric acid was, therefore, varied from 1 to 4 c. c. Each sample of whole egg was divided into four 50-gram portions and each sample of yolk was divided into four 25-gram portions. Each portion of whole egg or yolk was extracted for two hours with 200 c. c. of hydrochloric acid solution, containing respectively 1, 2, 3 and 4 c. c. of concentrated hydrochloric acid and 8 grams of picric acid. The results are given in Table 1.

TABLE I

EFFECT OF VARYING THE AMOUNTS OF HYDROCHLORIC ACID

Sample No.	Hydrochloric acid, conc.	1 c. c.	2 c. c.	3 c. c.	4 c. c.
		Grams $Mg_2P_2O_7$ in 150 c. c. of filtrate			
1	Whole Egg	.0122	.0125	.0128	.0126
2	" "	.0140	.0140	.0144	.0147
3	" "	.0145	.0149	.0156	.0161
4	" "	.0182	.0181	.0185	.0194
5	" "	.0457	.0455	.0449	.0459
6	Yolk	.0167	.0171	.0172	.0183
7	"	.0161	.0170	.0175	.0177
8	"	.0160	.0163	.0171	.0175
9	"	.0146	.0148	.0154	.0157
10	"	.0158			.0170

Effect of Varying the Amounts of Picric Acid.—Duplicate determinations were made, one with 5 and the other with 10 grams of picric acid. Each sample of whole egg was divided into two 50-gram portions and each sample of yolk was divided into two 25-gram portions. Each portion of whole egg or yolk was extracted for two hours with 200 c. c. of hydrochloric acid solution, containing 2 c. c. of concentrated hydrochloric acid, and with 5 and 10 grams of picric acid respectively. The results are shown in Table II.

TABLE II

EFFECT OF PIRIC ACID

Sample No.	Picric Acid	5 Grams	10 Grams
		Grams $Mg_2P_2O_7$ in 150 c. c. of filtrate	
1	Whole Egg	.0138	.0141
2	" "	.0135	.0137
3	" "	.0449	.0450
4	" "	.0447	.0446
5	Yolk	.0156	.0158
6	"	.0154	.0156
7	"	.0164	.0165
8	"	.0161	.0158

Effect of Time.—Fifty-gram portions of whole egg and 25-gram portions of yolk were extracted with 200 c.c. of hydrochloric acid solution, containing 2 c. c. of concentrated hydrochloric acid, and 8 grams of picric acid. The time of extraction was varied from one-half hour to forty-eight hours. The results are given in Table III.

TABLE III.

EFFECT OF TIME

Sample No.	Hours	½	1	1	2	3	4	24	48
		Shaken by machine		Shaken by hand every 10 minutes				Shaken occasionally	
		Grams $Mg_2P_2O_7$ in 150 c. c. of filtrate							
1	Whole Egg	.0129			.0138			.0361	.0684
2	" "	.0139			.0148			.0309	.0505
3	" "		.0131		.0136				
4	" "		.0140		.0145				
5	" "	.0120		.0119					
6	" "	.0105		.0108					
7	" "	.0115		.0116					
8	Yolk	.0164		.0163					
9	"	.0145		.0145					
10	"	.0153		.0156					
11	"	.0138	.0139		.0148	.0152	.0164		
12	"				.0157	.0159	.0163		
13	"				.0145	.0150	.0156		

DISCUSSION

The results in Table I show that the amount of acid-soluble phosphoric acid extracted from eggs is affected by the amount of hydrochloric acid used in the extraction. The difference in magnesium pyrophosphate between two successive columns is slight but when columns 1 and 4 are compared the difference is quite marked. These results show that 1 c.c. of concentrated

hydrochloric acid is sufficient for the complete extraction of the acid-soluble phosphoric acid because increasing the amount of hydrochloric acid to 2 c.c. does not affect the results appreciably.

Table II shows that 5 and 10 grams of picric acid give the same results. The filtration is much quicker with 10 than with 5 grams of picric acid. For this reason 10 grams of picric acid would be more desirable than 5 grams. Since the effect of greater amounts than 10 grams of picric acid was not investigated, it is best to use a little less than 10 grams.

Table III shows that one-half hour and one hour extractions give practically the same results, but if the process is continued longer, more acid-soluble phosphoric acid is extracted.

The higher yield of acid-soluble phosphoric acid obtained when more than 2 c.c. of concentrated hydrochloric acid was used, or when the extraction was continued over one hour must be due to the disintegration of organically combined phosphorus. Therefore, the Chapin and Powick method of extraction was modified as follows: The amount of hydrochloric acid was changed from 10 c.c. of 2.5 normal (about 2 c.c. of the concentrated acid) to 1 c.c. of concenrated hydrochloric acid and the time of extraction was decreased to one hour.

RECOVERY OF ADDED PHOSPHORIC ACID

The modified Chapin and Powick method of extraction of acid-soluble phosphoric acid was tested by determining the amount of added phosphoric acid that can be recovered from eggs. The phosphoric acid was determined in a solution of disodium hydrogen phosphate by the official gravimetric method (9). The acid-soluble phosphoric acid was estimated in a sample of whole egg by the method described on page 8. A known volume of the disodium hydrogen phosphate solution was added to each of five aliquots of the sample of whole egg and the acid-soluble phosphoric acid again determined. The results are given in Table IV.

TABLE IV.

Recovery of Added Phosphoric Acid

Sample No.	1	2	3	4	5
Grams P_2O_5 in 50 grams of eggs.	.0153	.0153	.0153	.0153	.0153
Grams P_2O_5 added	.0550	.0550	.0550	.0550	.0550
Grams Total P_2O_5	.0703	.0703	.0703	.0703	.0703
Grams P_2O_5 found	.0700	.0697	.0699	.0698	.0699
Per cent recovery.	99.57	99.15	99.43	99.29	99.43

Maximum recovery—99.57 per cent.
Minimum recovery—99.15 per cent.
Average recovery—99.37 per cent.

Table IV shows a practically complete recovery of phosphoric acid added to eggs.

PLAN OF INVESTIGATION

To find the normal variations of the acid-soluble phosphoric acid in edible whole egg and yolk, twenty-five samples of each were selected. They varied from eggs one day old to the lowest grade obtainable in groceries in the Spring. To find the maximum amount of acid-soluble phosphoric acid that could be permitted in edible whole egg and yolk, ten samples of each were selected from weak eggs with slightly stuck yolks which could be set free by a quick twist of the egg. These eggs are edible according to Pennington, Jenkins and Betts (12). To determine whether the increase in the acid-soluble phosphoric acid in eggs is proportional to the degree of decomposition, spots, white rots and black rots were selected. The eggs were candled and examined out of the shell as described by Pennington, Jenkins and Betts (12). Each sample of whole egg consisted of two eggs and each sample of yolk consisted of the yolks of three eggs.

Cook (3) states the following: "Eggs in storage for one year show a loss of weight equivalent to 10 per cent of the total weight, which loss is largely water from the whites." Greenlee (13) reports a loss of moisture in the white and a gain in the yolk in cold storage. Since whole egg loses moisture and yolk gains moisture on standing, results on stale eggs cannot be compared with those on fresh eggs, unless calculated to a dry basis.

ACID-SOLUBLE PHOSPHORIC ACID AND WATER IN WHOLE EGG.

1. *Whole Egg of Good Quality.*

TABLE V.

A. *One Day Old.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams	
		Original Material	Dry Basis
1	72.94	20.9	77.2
2	75.40	23.5	95.5
3	73.00	22.9	84.8
4	72.31	21.3	76.9
5	74.18	21.4	82.8
Maximum	75.40	23.5	95.5
Minimum	72.31	20.9	76.9
Average	73.57	22.0	83.4 ±5.4

TABLE VI.

B. Highest Grade Obtainable in Groceries in the Spring.

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	73.39	22.4	84.2
2	72.89	22.9	84.5
3	73.93	24.0	92.1
4	74.69	21.8	86.1
5	73.31	23.3	87.3
6	73.06	22.1	82.0
7	73.63	23.2	88.0
8	72.59	24.1	87.9
9	73.62	20.1	76.2
10	72.34	25.5	92.2
Maximum	74.69	25.5	92.2
Minimum	72.34	20.1	76.2
Average	73.35	22.9	86.0 ±3.5

TABLE VII.

C. Lowest Grade Obtainable in Groceries in the Spring.

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	71.21	23.8	82.7
2	71.69	26.5	93.6
3	73.19	19.3	72.0
4	72.43	22.7	82.3
5	71.85	25.1	89.2
6	72.68	19.9	72.8
7	73.88	21.4	81.9
8	72.98	20.5	75.9
9	71.40	21.9	76.6
10	72.63	21.2	77.5
Maximum	73.88	26.5	93.6
Minimum	71.21	19.3	72.0
Average	72.39	22.2	80.5 ±5.5

TABLE VIII.

Summary of Results on Fresh Eggs of Good Quality (Tables V, VI and VII).

	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams	
		Original Material	Dry Basis
Maximum	75.40	26.5	95.5
Minimum	71.21	19.3	72.0
Average	73.01	22.5	83.3 ±5.3

TABLE IX.

2. *Whole Egg. Yolk Stuck to the Shell But Can Be Set Free by a Quick Twist of the Egg.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams	
		Original Material	Dry Basis
1	71.91	28.8	102.5
2	71.97	26.4	94.2
3	72.34	25.2	91.1
4	72.50	25.0	90.9
5	71.90	25.8	91.8
6	70.34	28.1	94.7
7	70.64	28.1	95.7
8	72.08	26.2	93.8
9	71.66	25.4	89.6
10	72.04	27.4	98.0
Maximum	72.50	28.8	102.5
Minimum	70.34	25.0	89.6
Average	71.74	26.6	94.2 ±2.8

TABLE X.

3. *Whole Egg. Held in Cold Storage Eleven Months.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams	
		Original Material	Dry Basis
1	70.63	28.8	98.1
2	71.66	26.1	92.1
3	71.00	27.3	94.1
4	71.36	28.8	100.6
5	71.54	29.1	102.2
6	72.21	28.7	103.3
7	71.74	31.9	112.9
Maximum	72.21	31.9	112.9
Minimum	70.63	26.1	92.1
Average	71.45	28.7	100.5 ±4.9

TABLE XI.

4. *Whole Egg. Yolk Stuck to the Shell But Can Be Set Free by Several Quick Twists of the Egg.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	68.49	30.1	95.5
2	69.07	30.9	99.9
3	69.25	35.3	114.8
4	70.09	31.8	106.3
5	67.85	34.0	105.8
6	70.35	30.0	101.2
7	68.86	33.5	107.6
8	70.52	26.2	88.9
9	72.54	28.4	103.4
10	72.56	24.2	88.2
Maximum	72.56	35.3	114.8
Minimum	68.49	24.2	88.2
Average	69.96	30.4	101.2 ±6.4

TABLE XII.

5. *Inedible Whole Egg. Heavy Spots. Yolk Stuck to the Shell and Cannot be Set Free by Twisting the Egg.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	71.30	28.8	100.0
2	70.78	28.7	98.2
3	72.22	29.4	105.8
4	70.22	36.1	121.0
5	67.78	32.6	101.2
6	69.73	29.6	97.8
7	63.60	46.4	127.5
8	63.83	41.2	113.9
9	67.66	34.6	107.0
Maximum	72.22	46.4	127.5
Minimum	63.60	28.7	97.8
Average	68.57	34.2	108.0 ±7.6

TABLE XIII.

6. *Inedible Whole Egg. Decomposed Frozen Eggs. Putrid Odor.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	70.00	46.2	154.0
2	69.02	52.1	168.2
3	69.24	54.6	177.5
4	70.41	44.8	151.4
5	69.45	51.6	168.9
Maximum	70.41	54.6	177.5
Minimum	69.02	44.8	151.4
Average	69.62	49.9	164.0

TABLE XIV.

7. *Inedible Whole Egg. White Rots.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	70.07	73.0	243.9
2	68.63	92.6	295.2
3	63.19	45.5	123.6
4	70.03	70.6	235.6
Maximum	70.07	92.6	295.2
Minimum	63.19	45.5	123.6
Average	67.98	70.4	224.6

TABLE XV.

8. *Inedible Whole Egg. Black Rots.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	64.41	229.4	644.6
2	69.55	142.7	468.6
3	73.13	178.1	662.8
4	74.51	184.0	721.9
Maximum	74.51	229.4	721.9
Minimum	64.41	142.7	468.6
Average	70.40	183.6	624.5

ACID-SOLUBLE PHOSPHORIC ACID AND WATER IN YOLK.

1. *Yolk From Fresh Eggs of Good Quality.*

TABLE XVI.

A. Yolk From Eggs One Day Old.

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	47.95	51.6	99.1
2	47.41	49.4	93.9
3	47.16	50.4	95.4
4	48.06	58.1	111.9
5	47.24	54.0	102.4
Maximum	48.06	58.1	111.9
Minimum	47.16	49.4	93.9
Average	47.56	52.7	100.5 ±5.3

TABLE XVII.

B. Yolk From the Highest Grade Eggs Obtainable in Groceries in the Spring.

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	49.01	52.0	102.0
2	49.67	50.2	99.7
3	49.10	53.8	105.7
4	49.48	62.1	122.9
5	49.64	54.6	108.4
6	50.06	56.8	113.7
7	50.15	55.3	110.9
8	50.42	53.2	107.3
9	49.48	53.5	105.9
10	49.34	51.3	101.3
Maximum	50.42	62.1	122.9
Minimum	49.01	50.2	99.7
Average	49.64	54.3	107.8 ±5.0

TABLE XVIII

C. Yolk From the Lowest Grade Eggs Obtainable in in the Spring.

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	50.69	49.9	101.2
2	50.20	58.9	118.3
3	49.87	52.4	108.1
4	48.91	56.3	110.2
5	48.52	56.3	109.4
6	50.02	49.9	99.8
7	49.35	52.8	104.2
8	49.52	48.8	96.7
9	49.70	51.0	101.4
10	50.06	44.8	89.7
Maximum	50.69	58.9	118.3
Minimum	48.52	44.8	89.7
Average	49.68	52.1	103.9 ±5.1

TABLE XIX.

Summary of Results on Yolk From Fresh Eggs of Good Quality (Tables XVI, XVII and XVIII).

	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
Maximum	50.69	62.1	122.9
Minimum	47.16	44.8	89.7
Average	49.24	53.1	104.8 ±6.0

TABLE XX.

2. *Yolk From Stale Eggs. Yolk Stuck to the Shell But Can Be Set Free by a Quick Twist of the Egg.*

	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams	
		Original Material	Dry Basis
1	51.39	53.4	109.9
2	51.73	59.2	122.6
3	51.01	59.6	121.7
4	50.88	55.2	112.4
5	51.12	47.6	97.4
6	50.71	47.9	97.2
7	51.45	53.4	110.0
8	51.17	55.6	113.9
9	52.43	52.4	110.2
10	52.49	52.7	110.9
Maximum	52.49	59.6	122.6
Minimum	50.71	47.6	97.2
Average	51.44	53.7	110.6 ±5.7

TABLE XXI.

3. *Yolk From Stale Eggs. Yolk Stuck to the Shell But Can Be Set Free by Several Quick Twists of the Egg.*

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams	
		Original Material	Dry Basis
1	52.70	54.1	114.4
2	51.46	54.7	112.7
3	51.29	55.8	114.6
4	52.33	50.8	106.6
5	53.03	53.3	113.5
6	52.75	56.9	120.4
7	51.59	54.3	112.2
8	52.71	56.0	118.4
Maximum	53.03	56.9	120.4
Minimum	51.29	50.8	106.6
Average	52.23	54.5	114.1 ±2.9

TABLE XXII.

4. Yolk From Eggs Which Were Held in Cold Storage Eleven Months.

No.	Water %	Acid-Soluble P_2O_5 Milligrams per 100 Grams Original Material	Dry Basis
1	52.97	66.4	141.2
2	52.83	55.5	117.7
3	53.90	57.8	125.4
4	53.89	56.7	123.0
5	54.55	57.4	126.3
6	54.30	59.2	129.5
Maximum	54.55	66.4	141.2
Minimum	52.83	55.6	117.7
Average	53.74	58.8	127.2 ±5.5

TABLE XXIII

SUMMARY OF RESULTS ON ACID-SOLUBLE PHOSPHORIC ACID IN WHOLE EGG AND YOLK

Whole Egg

	Acid-Soluble P_2O_5 mgs. per 100 grams, dry basis Min.	Max.	Average
1. Good quality	72.0	95.5	83.3 ± 5.3
2. Yolk stuck to the shell but can be set free by a quick twist of the egg	89.6	102.5	94.2 ± 2.8
3. Held in cold storage eleven months	92.1	112.9	100.5 ± 4.9
4. Yolk stuck to the shell but can be set free by several quick twists of the egg	88.2	114.8	101.2 ± 6.4
5. Yolk stuck to the shell and cannot be set free by twisting the egg	97.8	127.5	108.0 ± 7.6
6. Decomposed frozen	151.4	177.5	164.0
7. White rots	123.6	295.2	224.6
8. Black rots	468.6	721.9	624.5

Yolk

1. Good quality	89.7	122.9	104.8 ± 6.0
2. Yolk stuck to the shell but can be set free by a quick twist of the egg	97.2	122.6	110.6 ± 5.7
3. Yolk stuck to the shell but can be set free by several quick twists of the egg	106.6	120.4	114.1 ± 2.9
4. Held in cold storage eleven months	117.7	141.2	127.2 ± 5.5

DISCUSSION

Water in Whole Egg and Yolk.

The water content of whole egg was found to vary from 75.40 per cent (Table V) to 63.19 per cent (Table XIV). One day old eggs gave an average of 73.57 per cent of water. Eggs which were held in cold storage for eleven months gave an average of 71.45 per cent of water. The water content of yolk was found to vary from 47.16 per cent (Table XVI) to 54.55 per cent (Table XXII). Yolk from eggs one day old gave an average of 47.56 per cent of water. Yolk from eggs which were held in cold storage for eleven months gave an average of 53.74 per cent of water. These results show that whole egg loses moisture and yolk gains moisture on standing. Therefore, the acid-soluble phosphoric acid must be calculated on a dry basis.

Acid-Soluble Phosphoric Acid in Whole Egg.

In Table VIII are shown 25 samples of fresh eggs of good quality. These eggs were divided into three grades: one day old, the highest, and the lowest grades obtainable in groceries in the Spring. As a rule, only fresh eggs are sold in groceries in the Spring. Even the lowest grade eggs were of good quality. Table V shows that the acid-soluble phosphorus pentoxide in five samples of eggs one day old varies from 76.9 to 95.5 milligrams per 100 grams on a dry basis, and the average is 83.4 milligrams. The average deviation from the arithmetic mean is ± 5.4. The variations in the amount of acid-soluble phosphorus pentoxide in 10 samples of fresh eggs of the highest grade obtainable in groceries in the Spring are shown in Table VI. The minimum is 76.2, the maximum is 92.2, and the average is 86.0 milligrams per 100 grams on a dry basis. The average deviation from the arithmetic mean is ± 3.5. Table VII shows that the acid-soluble phosphorus pentoxide in 10 samples of fresh eggs of the lowest grade obtainable in groceries in the Spring varies from 72.0 to 93.6 milligrams per 100 grams on a dry basis, and the average is 80.5 milligrams. The average deviation from the arithmetic mean is ± 5.5. As stated above, only eggs of good quality were used in this series of 25 samples. If the increase in the amount of acid-soluble phosphoric acid in eggs is to be used as a test for decomposition, the lower grade eggs should not give higher results than the higher grade eggs, unless decomposition has set in. The results obtained on the three grades of eggs do not differ appreciably. A summary of the results of Tables V, VI and VII on 25 samples of fresh eggs of good quality is given in Table VIII. The minimum is 72.0, the maximum is 95.5, and the

average is 83.3 milligrams per 100 grams on a dry basis. The average deviation from the arithmetic mean is ± 5.3.

In Table IX are shown 10 samples of stale eggs. Fresh eggs were allowed to stand until the yolks stuck to the shells but could be set free by a quick twist of the eggs. These eggs are considered edible (12). The acid-soluble phosphorous pentoxide in these eggs varies from 89.6 to 102.5 milligrams per 100 grams on a dry basis, and the average is 94.2 milligrams. The average deviation from the arithmetic mean is ± 2.8. The minimum, maximum and the average results are higher than those obtained on eggs of good quality (Table VIII). These results show that after decomposition has set in, as shown by candling and physical examination out of the shell, the acid-soluble phosphoric acid is increased.

Table X shows 7 samples of eggs which were held in cold storage for eleven months. The condition of these eggs was as follows: the air spaces were movable, the yolks separated from the whites with great difficulty, the whites were very thin and slightly colored yellow and the eggs had a perceptible odor. The acid-soluble phosphorus pentoxide in these eggs varies from 92.1 to 112.9 milligrams per 100 grams on a dry basis, and the average is 100.5 milligrams. The average deviation from the arithmetic mean is ± 4.9.

In Table XI are shown 10 samples of eggs of a doubtful nature. These eggs cannot be classed as edible or inedible. The eggs of this series were allowed to stand until the yolks stuck to the shells but could be set free by several quick twists of the eggs. As a rule, a candler does not twist an egg before the candle more than two or three times. The average candler might pass some of the eggs of this series as edible, but not all. The acid-soluble phosphorus pentoxide in these eggs varies from 88.2 to 114.8 milligrams per 100 grams on a dry basis, and the average is 101.2 milligrams. The average deviation from the arithmetic mean is ± 6.4. The minimum, maximum, and the average results are higher than those obtained on eggs of good quality (Table VIII). The maximum and the average results are higher than those obtained on eggs the yolks of which stuck to the shells but could be set free by a single quick twist of the eggs (Table IX). The difference in age between eggs of Table IX and Table XI may be only a few days.

Table XII shows nine samples of heavy spots. The yolks of these eggs were stuck to the shells and could not be set free by twisting the eggs. This grade of eggs is considered inedible. The acid-soluble phosphorus pentoxide was found to vary from 97.8 to 127.5 milligrams per 100 grams on a dry basis, and the average is 108.0 milligrams. The average deviation from the arithmetic mean is ± 7.6. On further decomposition, spots are

changed to white rots and these in turn are changed to black rots. Table XIV shows four samples of white rots. The acid-soluble phosphorus pentoxide in these eggs varies from 123.6 to 295.2 milligrams per 100 grams on a dry basis, and the average is 224.6 milligrams. Table XV shows four samples of black rots. The acid-soluble phosphorus pentoxide in these eggs varies from 468.6 to 721.9 milligrams per 100 grams on a dry basis, and the average is 624.5 milligrams.

In Table XXIII is given a summary of results on eight grades of whole egg used in this investigation. Excluding numbers 3 and 6, this table is arranged in the order of the gradual decomposition of eggs. The results show a progressive increase in the acid-soluble phosphoric acid from an average of 83.3 milligrams of phosphorus pentoxide per 100 grams in eggs of good quality to an average of 624.5 milligrams in black rots.

Acid-Soluble Phosphoric Acid in Yolk

In Table XIX are shown 25 samples of yolk from fresh eggs of good quality. As in the case of whole egg, the yolks of this series also were divided into three grades: from eggs one day old, from the highest, and from the lowest grades of eggs obtainable in groceries in the Spring. The eggs of this series were of the same quality as those described in Table VIII. Table XVI shows five samples of yolk from eggs one day old. The acid-soluble phosphorus pentoxide in these yolks was found to vary from 93.9 to 111.9 milligrams per 100 grams on a dry basis, and the average is 100.5 milligrams. The average deviation from the arithmetic mean is ± 5.3. The variation in the amount of acid-soluble phosphorus pentoxide in 10 samples of yolk from the highest grade eggs obtainable in groceries in the Spring is shown in Table XVII. The minimum is 99.7, the maximum is 122.9, and the average is 107.8 milligrams per 100 grams on a dry basis. The average deviation from the arithmetic mean is ± 5.0. Table XVIII shows that the acid-soluble phosphorus pentoxide in 10 samples of yolk from eggs of the lowest grade obtainable in groceries in the Spring varies from 89.7 to 118.3 milligrams per 100 grams on a dry basis, and the average is 103.9 milligrams. The average deviation from the arithmetic mean is ± 5.1. The results obtained on these three grades of yolk do not differ appreciably. A summary of the amount of acid-soluble phosphorus pentoxide found in 25 samples of yolk from fresh eggs of good quality (Tables XVI, XVII and XVIII) is given in Table XIX. The minimum is 89.7, the maximum is 122.9, and the average is 104.8 milligrams per 100 grams on a dry basis. The average deviation from the arithmetic mean is ± 6. Of the 25 samples of yolk, 23 contain less than 114 milligrams.

Table XX shows 10 samples of yolk from eggs the yolks of which stuck to the shells but could be set free by a quick twist of the eggs. These eggs were of the same grade as those described in Table IX. The acid-soluble phosphorus pentoxide was found to vary from 97.2 to 122.6 milligrams per 100 grams on a dry basis, and the average is 110.6 milligrams. The average deviation from the arithmetic mean is ± 5.7. The minimum and the average results are higher than those obtained on yolk from eggs of good quality (Table XIX), but the maximum is the same.

In Table XXI are shown 8 samples of yolk from eggs of the same grade as those described in Table XI. The eggs of this series were allowed to stand until the yolks stuck to the shells but could be set free by several quick twists of the eggs. The acid-soluble phosphorus pentoxide in these yolks varies from 106.6 to 120.4 milligrams per 100 grams on a dry basis, and the average is 114.1 milligrams. The average deviation from the arithmetic mean is ± 2.9. The minimum and the average results are higher than those obtained on yolks from eggs of good quality (Table XIX), but the maximum is lower.

Table XXII shows 6 samples of yolk from eggs which were held in cold storage for eleven months. These eggs were of the same quality as those described in the discussion of Table X. The acid-soluble phosphorus pentoxide was found to vary from 117.7 to 141.2 milligrams per 100 grams on a dry basis, and the average is 127.2 milligrams. The average deviation from the arithmetic mean is ± 5.5. In these yolks the minimum, maximum and the average results are higher than those obtained in yolk from eggs of good quality (Table XIX).

SUMMARY AND CONCLUSIONS

1. Chapin and Powick's method for the extraction of the acid soluble phosphoric acid from eggs was modified as follows: the amount of hydrochloric acid was changed from 10 c. c. of 2.5 normal to 1 c.c. of concentrated acid in 200 c.c. of water and the time of extraction was decreased to one hour.

2. Whole egg was found to lose moisture and yolk was found to gain moisture on standing. Therefore, the acid-soluble phosphoric acid must be calculated on a dry basis, to secure comparable results.

3. The amount of acid-soluble phosphorus pentoxide in 25 samples of fresh eggs of good quality was found to vary from 72 to 95.5 milligrams per 100 grams on a dry basis. These eggs were divided into three grades: one day old, the highest, and the lowest grades obtainable in groceries in the Spring. The results obtained on these three grades of whole egg do not differ appreciably, showing that whatever the age of an egg, as long as candling and physical examination out of the shell do not show any signs of decomposition, the amount of acid-soluble phosphoric acid is not increased.

4. The amount of acid-soluble phosphorus pentoxide in 25 samples of yolk from eggs of good quality was found to vary from 89.7 to 122.9 milligrams per 100 grams on a dry basis. The yolks of this series were divided into three grades: from eggs one day old, from the highest, and the lowest grades of eggs obtainable in groceries in the Spring. The results obtained on these three grades of yolk do not differ appreciably.

5. The amount of acid-soluble phosphoric acid in eggs was found to increase on decomposition, the increase depending upon the degree of deterioration.

6. This investigation was carried out on small samples in order to bring out the greatest variations possible in the amount of acid-soluble phosphoric acid in whole egg and yolk. Each sample of whole egg consisted of two eggs and each sample of yolk consisted of the yolks of three eggs.

7. The results obtained in this investigation warrant the further study of the acid-soluble phosphoric acid in eggs on a commercial scale.

References

1. Chapin, R. M., and Powick, W. C., J. Biol. Chem. XX, p. 97, 1915.
2. Sherman, H. C., Food Products, New York, 1916, p. 137.
3. Cook, F. C., Bulletin No. 115, Bureau of Chemistry, United States Department of Agriculture, 1908.
4. Atwater, W. O., and Bryant, A. P., Bulletin No. 28 (Revised Edition) United States Department of Agriculture, 1906.
5. Leach, A. E., Food Inspection and Analysis, New York, 4th Edition, 1920, Page 271.
6. König, J., Chemie der Menschlichen Nahrungs-und Genussmittel, Berlin, 4th Edition, 1904, Vol. II, p. 575.
7. Halliburton, W. D., Handbook of Physiology, Philadelphia, 11th Edition, 1913, p. 429.
8. MacLean, H., Lecithin and Allied Substances, The Lipins, London, 1918, p. 17.
9. Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, Washington, 1920, p. 1.
10. Redfield, H. W., Bulletin No. 846, Bureau of Chemistry, United States Department of Agriculture, 1920.
11. Pharmacopoeia of the United States of America, 9th Edition, 1916, p. 471.
12. Pennington, M. E., Jenkins, M. K., and Betts, H. M., Bulletin No. 565. Bureau of Chemistry, U. S. Dept. of Agriculture, 1918.
13. Greenlee, A. D., Circular No. 83. Bureau of Chemistry, United States Department of Agriculture, 1911.

Biographical

Louis Pine was born in Russia on May 20, 1887. He entered Cooper Union Five-Year Night Course in Chemistry in 1908, and was graduated with a diploma in chemistry in 1913. He studied in the Polytechnic Institute, Brooklyn, from 1913 to 1916, and was graduated with the degree of Bachelor of Science in Chemistry in 1916. During 1916-1917 he pursued post-graduate studies in biological chemistry and physiology in Columbia University, and in 1917, received the degree of Master of Arts. He served in the United States Army from September, 1917, to August, 1919. After discharge from the Army he returned to Columbia University as a candidate for the degree of Doctor of Philosophy in 1920.

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